A NOTE ON THE MAGNITUDE OF JET-STREAM WINDS EAST OF JAPAN AS DERIVED FROM TRANSOSONDE DATA

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ABSTRACT

A comparatively unbiased set of wind statistics at jet-stream level from Japan eastward to the 180th meridian may be obtained from the United States Navy constant level balloon (transosonde) flights launched from Japan in 1957–59. Wind speeds so derived are presented as a function of time of year and longitude at pressure surfaces of 300 and 250 mb. At these longitudes and heights the average speed is 103 kt. in fall, 123 kt. in winter, and 101 kt. in spring. A comparison with mean meridional cross sections indicates that at these levels in this area of the northwestern Pacific the mean wind speed heretofore may have been underestimated by an amount exceeding 25 kt.

1. INTRODUCTION

Since the days of World War II, when United States bombers found themselves practically flying backwards over Japan, meteorologists have realized that the strongest tropospheric winds in the Northern Hemisphere (and perhaps in the world) occur over and to the east of Japan during the winter season [1]. It is not yet certain to what degree this is a reflection of the thermal wind resulting from large land-sea temperature differences on the east coast of a great continent, and to what degree it is associated with the air flow around the Himalayan Mountains.

Because of the strength of the wind in this area, estimates of the mean wind speed obtained from conventional vertical soundings (pibals, rawinsondes) are likely to be biased toward low values, since the greater the wind speed the greater the probability that the ascending balloon will be lost (and hence no data obtained) because of a low elevation angle. This difficulty led to the famous "relay" system of upper-air observation at Tateno, Japan, where the balloon is released considerably upwind from the ground observing post [2]. The Tateno "relay" system may give relatively unbiased wind statistics over Japan itself; yet for thousands of miles to the east of Japan, only Weather Ship Victor yields wind estimates. A weather ship can, to some extent, move with the balloon, but this advantage is probably nullified by the difficulty of making upper-air observations from a rolling and pitching platform. Thus, one might assume that the mean winds reported by Victor are biased toward low values. For completeness, we should also mention the possibility of using modern navigational equipment on aircraft, such as the Doppler radar, to estimate wind speeds. Although the speeds so obtained have been stated to be at least as accurate as those measured by rawinsonde [3], it is difficult to compile statistics from aircraft reports intermittent in time and space.

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An alternative method of obtaining wind information in such an area involves the use of the constant-level ballon (CLB). Since successive CLB positions (from which wind speeds are estimated) are not obtained through line-of-sight techniques, there is little tendency for CLB-derived winds to be biased toward low values. However, some small bias conceivably can result from a correlation between jet-stream winds and weather at the earth's surface—a CLB launch generally not being attempted with strong surface winds, rain, or cloud cover exceeding five-tenths (hazard to aircraft) and in this case, from the undesirability of launching if there is a likelihood that the balloons will drift over China. Another possible, but presumably very small, bias may result from the tendency (for which there is some slight evidence) of the transosondes to be entrained into the jet-stream core.

In addition to the reduction of wind-speed bias, the CLB has the advantage of yielding a space-and-time-integrated wind which should be more representative than the wind obtained at short time intervals from a rising balloon. The purpose of this paper is to present wind statistics derived from such a CLB system, and to make some comparisons with wind statistics previously obtained by more conventional methods.

2. PROCEDURES

During the period from September 1957 to April 1959, the United States Navy released nearly 250 constant-level balloons (transosondes) from Iwakuni Naval Air Station (34°N., 132°E.) in southwestern Japan [4]. The Japanese Islands are too far removed from the centroid of the Federal Communications Commission (FCC) radio direction finding (RDF) network to permit accurate positioning by this excellent network. On the other hand, the U.S. Navy network in the northwestern Pacific lacks the finesse of the FCC network. Determination of the average wind-speed error to be expected from RDF positioning in the northwestern Pacific is not easy since the true transosonde positions are unknown. However, an estimate may be derived from comparisons of simultaneous FCC and U.S. Navy RDF fixes in this area. From this it is apparent that, even though transosonde positions were obtained every 2 hours (with some exceptions), one cannot with confidence use the 2-hourly displacements as an indication of wind speed. As a result, it is impossible from these data to investigate the fine-scale structure of the Japanese jet and hence to measure the extremes in wind speed. However, by determining transosonde displacements over 6-hour intervals based on transosonde positions smoothed over 6 hours (average of three successive 2-hourly positions), it is found that on the average (148 comparisons) the 6-hour average wind speed determined from the FCC fixes differed from that derived from Navy fixes by 13 kt. This is not excessive for our purposes, especially when it is realized that, since both sets of position fixes presumably are in error, the average deviation from the true mean wind speed should be less than this.

Based on these smoothed winds, the wind speed as a function of longitude was evaluated, and wind speeds were then determined at 10° longitude intervals from 140°E. to the 180th meridian on all transosonde flights which transited the latter meridian. A difficulty was experienced with the first 6-hour average wind inasmuch as during part of this time the transosonde was ascending through layers of relatively weak wind. With the assumption of a linear increase in wind speed from the surface to float level, and an ascent time of about 1 hour a corrective factor of 1 in 12 was obtained. As a first approximation, therefore, the initial 6-hour average wind speed was increased by 10 percent.

3. TRANSOSONDE-DERIVED WIND SPEEDS

Table 1 gives monthly mean wind speeds derived from 6-hour transosonde displacements at pressure surfaces of 300, 250, and 150 mb., as well as the number of cases (flights) upon which the means are based. In order to get some feeling for the representativeness of these monthly means, let us examine the 300-mb. January mean wind speed of 131 kt. (at all longitudes from 140°E. to 180°) which is based on 50 observations (10 flights crossing 5 longitudes each). The standard deviation of these 50 observations is 31 kt., and consequently the standard deviation of the mean (if one assumes a normal distribution of speeds) is 4.4 kt. (standard deviation of the mean equals the standard deviation divided by the square root of the number of cases). Thus, according to customary statistical procedures, there allegedly is a 2.5 percent chance that the true mean wind speed at 300 mb. in January over these longitudes is less than 122 kt. and a 2.5 percent chance that it is greater than 140 kt. A complication arises, however, because the winds at nearby longitudes tend to be correlated and thus one might argue that instead of 50 observations there are, in reality, only 10 *independent* observations, in which case the standard deviation of the mean is 9.8 kt. rather than 4.4. kt. In the following the assumption has been made that the CLB-derived winds at nearby longitudes are independent,

TABLE 1.—*Mean-monthly transosonde-derived wind speed (in knots) as a function of longitude (°E.) and pressure-height*

	300 mb.							250 mb.							150 mb.						
	Cases	140°E.	150°	160°	170°	180°	Av.	Cases	140°E.	150°	160°	170°	180°	Av.	Cases	140°E.	150°	160°	170°	180°	Av.
Sept	7	76	71	87	83	89	81														
Oct	9	97	95	100	92	93	95	6	96	107	129	128	134	119							
Nov	9	99	111	117	129	126	116	16	111	110	120	120	109	114							
Dec	13	118	106	113	114	97	110	13	126	131	129	130	112	126							
Jan	10	120	136	143	132	122	131	13	141	127	121	123	114	125							
Feb	3	158	165	165	142	123	151	10	129	118	119	107	101	115	6	157	147	136	131	126	139
Mar	11	98	91	97	97	92	95	11	133	121	131	136	117	128							
Apr	6	107	79	91	103	75	91	8	134	110	103	88	88	105							
May	9	61	75	103	103	104	89														
Average		101	100	110	110	102			125	119	122	120	110								

TABLE 2.—*Mean-seasonal transosonde-derived wind speed (in knots) as a function of longitude (° E.) and pressure-height. Numbers in parenthesis indicate the standard deviation of the speed*

	300 mb.							250 mb.						
	Cases	140° E.	150°	160°	170°	180°	Av.	Cases	140° E.	150°	160°	170°	180°	Av.
Fall	25	92 (28)	94 (29)	102 (28)	103 (32)	104 (33)	99 (30)	29*	100 (31)	100 (31)	114 (31)	113 (38)	109 (38)	107 (34)
Winter	26	123 (26)	124 (31)	131 (30)	125 (34)	110 (39)	123 (32)	36	132 (29)	126 (30)	124 (33)	121 (38)	110 (33)	123 (33)
Spring	26	87 (35)	83 (25)	98 (36)	100 (33)	92 (34)	92 (33)	28*	110 (51)	103 (45)	114 (36)	112 (37)	105 (32)	109 (40)
Average		(30)	(28)	(31)	(33)	(35)			(36)	(35)	(33)	(38)	(34)	

*September and May winds at 300 mb.

but in judging the significance of the difference between CLB-derived wind speed and wind speed estimated by conventional means the reader should remain aware of this alternative way of viewing the statistics.

Perhaps the most surprising feature from table 1 is the evidence that, at least at 300 mb., the strongest winds are not over Japan itself but considerably to the east thereof. Even at 250 mb. there is evidence for a secondary speed maximum at 160°–170° E. We shall see later that it is in this area that previous mean wind speed estimates appear most in error. One might also note the large wind speeds at 150 mb. in February, confirming that strong winds extend to high levels in the northwestern Pacific.

Table 2 shows mean-seasonal transosonde-derived wind speeds, where winter is assumed to comprise the months of December, January, and February. As a matter of interest, the standard deviation of the seasonal wind speed is also presented. Inasmuch as there were no 250-mb. transosonde flights in September or May, in compiling the fall and spring means at this level we have used 300-mb. winds for these months. Thus, if anything, the magnitude of the 250-mb. mean wind during fall and spring has been underestimated. The standard deviations indicate that the wind speed is much steadier during fall and winter than during spring. The steadiness of the fall winds is somewhat surprising.

Statistics concerning the mean wind speed present only part of the story. Histograms of the transosonde-derived wind speed for fall, winter, and spring at 300 and 250 mb. (fig. 1) give some idea of the distribution of wind speeds. Despite the great smoothing of the wind alluded to previously, wind speeds in excess of 200 kt. do appear. Note that in our case this means that the wind speed exceeded 200 kt. for a distance of at least 1200 n. mi. Such winds occurred 2 percent of the time at 300 mb. in winter, 3 percent of the time at 250 mb. in winter, and 2 percent of the time at 250 mb. in spring. Inspection of individual transosonde flights showed that during both years the very strongest winds occurred in late February or early March.

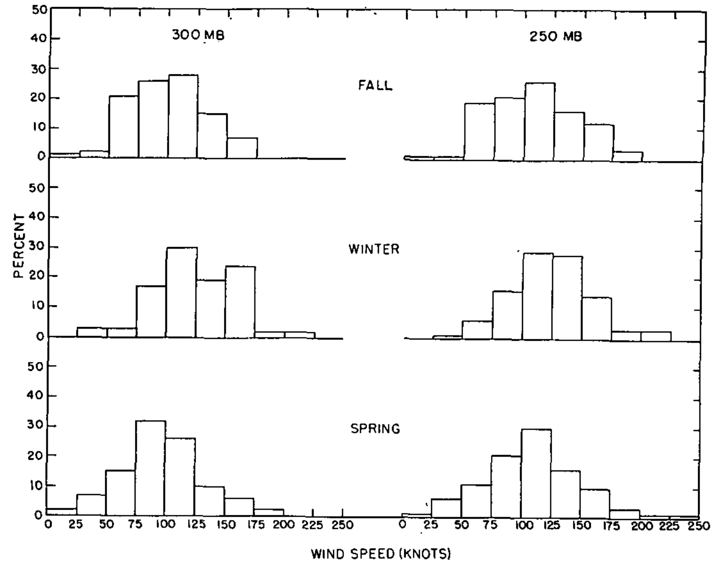

Figure 1.—Distribution of transosonde-derived wind speeds during fall, winter, and spring at 300 and 250 mb. from 140°E. to 180°.

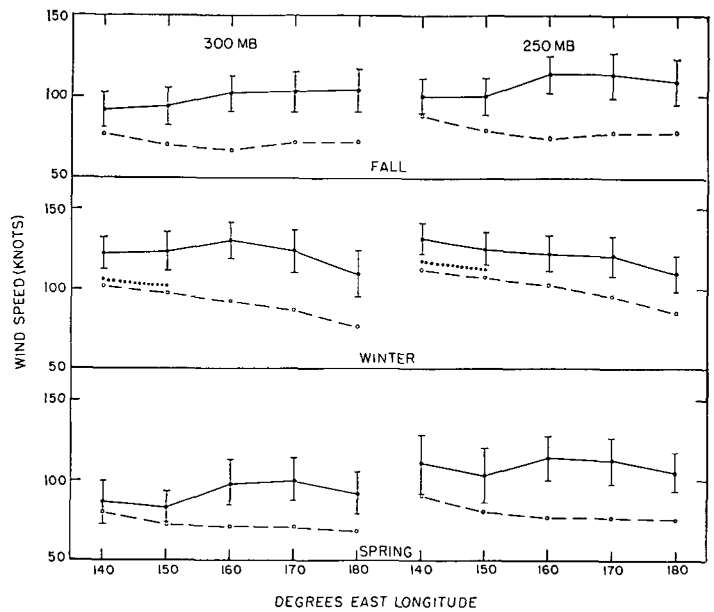

Figure 2.—Comparison between mean transosonde-derived wind speed (solid line) as a function of pressure, season, and longitude, and mean wind speed derived from [5] (dashed line). The dotted lines represent revised mean wind speeds presented in [5] based on Tateno "relay" soundings. Vertical lines extend two standard deviations of the mean (with the assumption that wind speeds at nearby longitudes are independent) either side of the transosonde mean wind.

4. COMPARISON BETWEEN WIND SPEEDS OBTAINED FROM TRANSOSONDES AND FROM CONVENTIONAL SOURCES

Crutcher's [5] excellent paper, based to a large extent upon statistics published by the U.S. Navy [6], presents, among other things, meridional cross sections of mean seasonal wind speed over the Northern Hemisphere at pressure surfaces of 100 mb. and higher. Figure 2 shows comparisons between transosonde-derived wind speeds east of Japan and the mean wind speeds presented by Crutcher. In order to make the comparison conservative, the maximum wind speed at the appropriate pressure surface and longitude was extracted from the meridional cross section regardless of the degree of compatibility of the latitude of this maximum with the mean transosonde latitude. This adds to the striking nature of the difference in mean seasonal wind speed derived from the two sources. The vertical lines centered on the mean transosonde wind speeds extend two standard deviations of the mean (with the assumption that wind speeds at nearby longitudes are independent) either side of the mean. Hence, in accordance with the earlier discussion, from one point of view there is only a 2.5 percent chance that the true seasonal mean wind speed, as estimated from the transosondes, is

TABLE 3.—*Transosonde-derived wind speed minus wind speed extracted from [5] (in knots). Average from 140°E. to 180°*

	Pressure (mb.)		
	300	250	150
Fall	28	*29	
Winter	31	22	**54
Spring	20	*29	

*Transosonde winds at 300 mb. during September and May.
**Transosonde winds only during February.

less than that indicated by the lower extremity of these vertical lines. To be emphasized is the fact that only once in 30 comparisons does the seasonal mean wind speed derived from the meridional cross section fall within the extent of these vertical lines. Table 3 gives the average difference in wind speed estimate for all the longitudes under discussion. With the exception of that for 150 mb., this difference is fairly consistent and averages about 27 kt. The much larger difference at 150 mb. is based upon only six observations in February, but may well indicate an increase in discrepancy with increase in height, a result which might be expected.

Of even more interest is the observation that, although the difference between transosonde-derived wind speed and the wind speed derived from the meridional cross sections averages only 15 kt. at 140°E., it averages 20, 33, 32, and 29 kt. at 150°E., 160°E., 170°E. and 180°, respectively. Thus, as perhaps might have been anticipated, while the mean wind speed over Japan appears heretofore to have been underestimated by only about 13 percent, over the ocean to the east of Japan the underestimate appears as large as 28 percent. The large discrepancy in the latter case is associated with the fact that the data in [5] show the mean wind speed decreasing to the east of Japan, whereas the transosonde-derived data show a tendency for the wind speed to increase to 160°–170°E.

It is apparent that Crutcher had suspicions concerning the magnitude of the mean wind speed east of Japan as derived from the U.S. Navy publications [6]. Thus, in Part 6 of the Introduction to [5], he mentions the findings of Sissenwine et al. [7] with regard to the wind speeds indicated by the Tateno "relay" soundings, and presents revised meridional cross sections at 130°E., 140°E., and 150°E. for the winter season. These revised estimates are shown in figure 2 by the dotted line. Although these revisions only partly reduce the discrepancies with the transosonde-derived mean wind speeds at the given pressure surfaces, it should be pointed out that at 200 mb. the revised wintertime cross section shows a closed isopleth of 130 kt. at 140°E. Accordingly, the difficulty may lie in the height of the jet core as well as in the magnitude of the wind in the jet core.

Of course, there is also the possibility that the two years during which transosonde flights were carried out were unusual in the sense that an abnormally strong jet existed to the east of Japan, and data presented by the reviewers of this paper suggest that to some extent this may be the case. For example, the data of Muench and Borden [8] show that during the biennium 1958–59 (the climax of some of the strongest solar activity of the century, incidentally) the wintertime wind speed between 30° and 40°N. exceeded that observed during 1956–57 by about 2 kt. at 140°E. and by about 21 kt. at 180°. On the other hand, the wind data from Midway and Iwo Jima are not so conclusive on this point, indicating, in each case, that the wind speed was above the 10-yr. normal during one of the two years under study and below the normal during the other year. Thus, an upward revision of the mean wind speed in the northwestern Pacific is undoubtedly warranted, although the magnitude of the revision may not be as great as suggested by the transosonde flights during 1957–59.

5. CONCLUSION

The transosonde-derived wind statistics at 300 and 250 mb. during 1957–59 make it appear that the mean wind speed has been heretofore underestimated by about 13 percent over Japan and by about 28 percent at 160°–170°E. However, since the jet may have been unusually strong during these two years, the corrections indicated may be a maximum and may not be representative for a longer time period.

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